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USE OF SECONDARY RECOVERY METHODS IN KAZAKHSTAN OIL FIELDS

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Certain geological peculiarities and special operating conditions appear to favor the use of secondary recovery methods in the Kazakhstan oil industry. These peculiarities and conditions are as follows:

1. Most of the oil beds in Emba Oblast are shallow. Oil was obtained from a depth not exceeding 450 meters in 85 percent of the wells, and only 15 percent produced oil from a depth greater than 850 meters. A majority of the wells were drilled in the ratio of one well per hectare, and the density was still greater in some beds.

2. In some cases this condition brought about a rapid expenditure of the bed's potentiality. In other cases it contributed to a quick inflow of the water around the bed, which caused a great amount of oil to remain untapped.

According to data from the Makat test wells, the saturation of Jurassic horizon I residual oil amounted to 60-65 percent of the volume of pores.

3. The oil yield of the majority of wells is small.

4. The existence of a considerable number of oil beds containing an exceptionally high-quality oil.

Jurassic horizon II in Dossor and Jurassic horizon I in Makat were the first to be subjected to water-flooding operations.

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Utilization of Water Flooding in the Dossor Oil Wells

The oil bed of Jurassic horizon II is considered a middle Jurassic deposit. In structure this bed represents a dome-shaped fold, bordered by a fault to the south and to the west.

According to experiments made by the TsNIL of the Kazakhstanneft', the physical dimensions of the oil sands in the stratum are as follows: 5 percent are 0.25-0.1 millimeter, 20.4 percent are 0.1-0.01 millimeter, and 55.3 percent are smaller than 0.01 millimeter.

The average porosity of the sands as determined from five specimens varies from 25 to 30 percent. The permeability of the sands can be estimated by the amount of water absorbed by the wells in the various parts of the structure. For instance, well No 139, in the western part of the structure, absorbed 24 cubic meters of water in 24 hours, while well No 77, at the eastern border, absorbed up to 140 cubic meters of water in 24 hours. Consequently, the permeability increases from west to east. For this reason, the oil field chosen to be flooded first was in the eastern part of the structure.

When water flooding was started, yields of a well of horizon II varied from 0.1 to 1.2 tons. The less productive wells were located in the western part of the layer, whereas in the eastern part, yields increased to 1.2 tons. This confirmed the lower permeability of the western part's collectors, as compared to those of the eastern part of the structure.

Water flooding was first used in the Dossor oil fields on 28 August 1943. With the existing network of wells, arranged in parallel rows, only linear water flooding could be undertaken.

Water pumped into the stratum came from two "sor" (lakes of 65 hectares in area), with an average depth of 0.4-0.7 meter. Weirs were built in the deepest part (1.5 meters) of the sor. The water flowed freely from the weirs into a horizontal settling tank, with a capacity of 250 cubic meters, from which it was pumped to the sectors to be flooded.

Two pumps were installed in the pumping stations, one a Kolomna type and the other a Gardner-Denver. These were driven by 35-kilowatt electric motors. A 4-inch main was laid from the pumping station, with 2-inch branches running to the injection wells. The injection wells were equipped with manometers and with control valves for flooding the wells with the back pressure. The quantities of injected water were measured with Voltman meters installed on the main.

The first flooded sector was initially composed of eight injection and 16 production wells. At first, 500-800 cubic meters of water were pumped every 24 hours into each of the eight wells under a pressure of 11 atmospheres at the well head.

The salinity of the pumped water measured 20 to 24 degrees Baume and contained up to 4 milligrams per liter of physical impurities. The action of the water was observed in the nearest wells, one month after the beginning of the injection.

The yield of wells No 78 and No 24 increased by 90 percent. Later, a great increase (up to 300 percent) was observed in the yield of well No 103, and 3 months later, ten out of the 16 wells gave a production 63 percent greater than the initial output.

According to the 1 July 1947 statement of work, 244,000 cubic meters of water were pumped into Jurassic bed II through the injection wells.

As a result of the water flooding, several additional thousand tons of oil were obtained from the wells of the first sector by 1 July 1947. The daily oil output reached its maximum in June 1945, and represented 220 percent of the initial yield; it leveled off about 1 July 1945 at 160 percent.

The greatest increase in production was observed in wells which had been subjected to a four-sided action from injection wells. Notwithstanding some deviation from a regular geometrical network of injection wells and also a lack of regulation of the progress of flooding, the method produced considerable efficiency in the first sector, and the result was stimulating to its development.

The second sector selected for flooding operations was in the southern part of the bed. The flooding operation, started 27 April 1945, initially comprised six injection and 22 production wells.

At the beginning of the operation, up to 400 cubic meters of water were pumped into the injection wells per 24 hours; then the volume was decreased to 100 cubic meters. From 27 April 1945 to 1 January 1946, 34,088 cubic meters of water were pumped into the injection wells. For each injection well the water averaged up to 25 cubic meters per 24 hours. The pressure at the head, at the above-indicated rate of flow, varied between 0 and 10 atmospheres.

Later, the number of injection wells was increased to 11. Three injection wells were located outside the oil-bearing limits of the area. Flooding through these wells was discontinued because the results obtained in this operation were unsatisfactory.

In general, data gathered on the flooding operations in the second sector show that here better results were obtained in the wells which fell under the conditions of the usual linear flooding. Thus, the yield of wells No 207, 52, 114, 43, and 97 increased from 50 to 250 percent.

The flooding through wells located outside the oil-bearing area gave no positive results due to a thorough flooding of the boundary area and the impossibility of pumping more water into it.

More than 10,000 tons of additional oil have been obtained from both Dossor sectors as a result of the water flooding since the beginning of the operation.

Utilization of Water Flooding in the Makat Oil Wells

Jurassic horizon I, the most productive of the site, was chosen for the utilization of the flooding method. The formation chosen for flooding presented an inclined dome-shaped fold, stretching from northwest to southeast. Jurassic deposits are regular with no tectonic deformation. Neocomian formations constitute the core of the dome. Salt is deposited about 680 meters deep in the center of the dome. Jurassic horizon I is embedded on top of the middle Jurassic formation and is composed of a series of oil-bearing sands, of clays with a coal interlayer, and of sandstone. The sands are fine-grained. Silt particles are predominant, their size varying from 0.06 to 0.10 millimeter.

From operational results, it was established that initial productivity was dependent on the depth of penetration into the sands and on their lithologic composition. Thus, for instance, assuming the yield of well

No 109 to equal 100 percent when the horizon was penetrated only 3 meters, this yield becomes 30 percent greater for a 8.2-meter penetration, and at 10.8 meters the increase is 230 percent. Such progression was also observed in many other wells.

The initial pressure in the bed was about 14-15 atmospheres. As work progressed in the horizon, the average yearly decrease in the bed's pressure was about 0.5 atmospheres. At the beginning of the water-flooding operation (1944) the pressure was 4.6 atmospheres, increasing up to 7.0 atmospheres toward the borders of the bed.

Over 90 percent of the wells contain water. Only 10 percent of the wells produce oil without water. As a rule the yield of such wells is low. Other wells produce a certain amount of water with oil.

At the initial stage of the work, the horizon was characterized by the coexistence of three conditions: gas pressure in the central part of the dome, water (weak activity of contour water) in the wall sections, and dissolved gas in the intermediate zone.

The dissolved gas and gas conditions were most pronounced during the initial stage of the horizon's development, evidence of which is provided by data on high gas factors (up to 200-250 cubic meters per ton).

The increased water content of the wells located in the wall sections of the dome and the relatively large water flow into them indicate a definite, although slight, activity of the contour water, with the oil progressing through the bed toward the oil well opening. The pressure of contour water, however, was not sufficient to move the oil from its bed to the wells, and the role of water pressure was reduced to that of refilling the pore space freed from oil and gas. At present, the condition of the horizon I deposit in the southeast and central parts of the dome is approximately gravitational.

According to data on test well KO-2, the residual oil saturation takes up 60 percent of the pore space for the whole horizon. Water saturation exceeding 60 percent of the pore space is characteristic of the lower strata of the horizon, while in the upper parts it is considerably lower.

The first industrial and experimental flooding operation was started in August 1944. The first flooded sector is located in the northeastern part of the dome, and comprises nine injection and 25 production wells. Old production wells were used for injection.

The percentage of water in the wells approached an average of 77 percent, but the absolute quantities of water obtained from the wells were not large. The construction of the wells includes a single shaft with the casing packer above the top of the Jurassic bed; the perforated bottom of the shaft is opposite the productive part of the horizon.

The water-flooding equipment is composed of a pumping station with two NG-3 units, a settling and storage watertank, and suction and delivery piping. The whole system is primarily designed to pump the lake water into the injection wells, adding to it, in summer, water from the bed to lower the salt concentration. No provision was made for water-purification equipment because of the high coagulating power of the lake water. The amount of water injected was regulated with Schaeffer tubes. The consumption of injected water was measured by differential manometers; later Voltman meters were used. Operation of the equipment is indicated by the following table:

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[redacted]

	1944 (5 mos)	1945	1946	1947 (6 mos)	Totals
Operation (in hr)	2,995	7,475	5,705	4,344	20,519
Interruption (in hr)	501	1,285	3,055	216	5,057
Avg pressure (in atm)	6-10	7-10	10-12	9-10	9-10
Avg salinity of water pumped (in °Baume)	20-22	22-23	20-24	20-23	22-23
Vol of water pumped (in cu m)	51,690	154,474	207,240	98,736	512,140
No of injection wells	9	24	24	15	-
No of production wells	24	60	62	62	-

The wells operated at the limit of their water-intake capacity under a pressure of 11 atmospheres at the orifice.

The number of injection wells was increased from 9 to 24, but in May 1946 was reduced to 15. The average proportion of injection wells to production wells was 2-5. The total volume of water injected in horizon I since the start of operations was 512,140 cubic meters.

As a result of injecting this amount of water into the horizon, the average increase of bed pressure in sectors I and II was 1.6 atmospheres, the average for the whole horizon. In the zone where the injection operation was conducted, the pressure in the bed increased 1.5-2 times over the initial pressure.

From the start of injection, an additional quantity of several thousand tons of oil was obtained from the wells of sector I. For the same period of time, 244,000 cubic meters of water were pumped into the injection wells.

By February 1945 the average yield of the wells per 24 hours had increased threefold and later it remained steady at 200 percent of the initial yield; this appears to be very favorable, insuring a lasting and steady output as well as a high percentage yield of the bed's oil.

It is very important to stress the fact that, at the initial stage of flooding, the quantity of water injected was considerably larger than the quantity of liquid extracted, while in the last year of operation the quantities of liquids injected and extracted were equal.

Constancy of water content in the extracted oil was also noted. All this indicates the stabilization of the whole flooding operation and the achievement of a rational daily water injection system for each injection well (an average of 18-20 cubic meters).

As a result of the flooding, the maximum total yield of the oil wells in sector I was almost five times greater than the initial yield, with an average water factor equal to 15.

The results of water flooding in the Dossor and Makat oil fields have indicated the high efficiency of this method. This efficiency, however, could have been much greater if such factors as the close observance of a geometrically regular network of injection wells, the lithologic properties of collectors, the water level in the sector, the [redacted] 50X1-HUM

residual oil saturation, etc., had been taken into account.

After consideration of these defects, which were tolerated in the planning for the first two sectors (especially the second sector), the plan for developing flooding operations in the Jurassic horizon I in Makat was executed more scientifically.

Five test wells were drilled for testing the physical and geological properties of oil collectors and continuous core samples were taken from the productive horizon. The samples were studied with regard to their content of water and oil. A physical analysis was made of the composition of the oil-bearing sands, their coefficient of physical porosity was determined, and the viscosity of oil for various conditions in the bed was established. The reactions of injection and production wells on each other were also studied. Sectors for which injection was planned were divided beforehand into individual fields on the basis of their water and oil saturation. The quantity of water injected per well was determined on the basis of the collectors' permeability, calculated according to operating data and the effective thickness of the stratum traversed in a given well.

The new sector selected possessed the most favorable geological conditions. It is entirely suited for flooding operations because in its selection the following considerations were taken into account: (1) thickness of the horizon, large oil-bearing area, and little variation in collectors; (2) condition of dissolved gas in the deposit of the selected sector, at the initial level of operations; (3) higher oil saturation of the collectors amounting to 60-65 percent of the pore space, according to data obtained from a study of cores from the test wells and a large quantity of residual oil.

In the selected sector the injection wells form a geometrically regular network approximating the five-point system, and the ratio of injection wells to production wells is 1:1. To obtain this ratio between injection and production wells, the drilling of nine new injection wells and four new production wells in the sector was planned. The flooded sector will include 35 injection wells and 40 production wells. The new injection and production wells will be drilled with a Crelius machine and will be equipped with 4-inch casing. To exclude strata highly saturated with water from the flooding operation, a selective perforation is planned for injection wells. To identify these strata when drilling all the new injection wells, full use will be made of BKZ.

The volume of water injected in each well is determined on a basis of not more than 2 cubic meters per meter of thickness of the productive stratum. It is planned to have the total volume of injected water reach 1,500 cubic meters per 24 hours. Five piezometric wells equipped with instruments recording the level in the well are planned for checking pressure variations in the bed of the flooded area.

To improve the quality of injected water (suppressing impurities and diminishing the corrosive action on pipes and on well equipment, etc.) the following water treatment has been provided: settling, separation from oil, coagulation, liming, and filtration. Control methods for the flooding operation have been carefully worked out.

The implementation of the conditions provided for in the project will undoubtedly increase to a considerable extent the efficiency of the flooding method and drastically cut down the unit cost of additional production.

Prospects for Utilization of Secondary Recovery Methods in Other Kazakhstanneft' Oil Fields

One of the first sites selected for the utilization of secondary recovery methods was Aptian horizon III in the second sector of the Sagiz oil field. This horizon is a very favorable site because of the homogeneous character of its lithologic composition, the absence of faults, its small thickness and area, a three-sided isolation (tapering), a considerable number of wells with small yield, the transition to the gravitational, and, finally, a relatively large quantity of residual oil. These geological and physical properties of the horizon and the analysis of geological and industrial materials led to the conclusion that the flooding method must be applied to this horizon.

The sector selected is in the eastern part of the Sagiz Dome in which horizons of the Cretaceous and Jurassic periods other than horizon III are being exploited.

Horizon III occurs at the bottom of the lower Aptian formation, 224-254 meters down, and lithologically is composed of sands changing to argillaceous formations to the south, southeast, and east.

On the east, the horizon III deposit is supported by contour water. The horizon's sands are fine-grained and highly homogeneous. The average porosity is 20 percent.

Among the 31 oil wells, there are 18 which yield a considerable amount of water together with oil.

The sector chosen for exploitation comprises 25 production and 25 injection wells. The project provides for drilling new injection wells. Water from a lake adjoining the exploited sector will be used for injection together with the water from the bed, which is extracted from the oil wells. The water-processing scheme is similar to that provided for the Makat oil field.

Test wells are already being drilled in the Sagiz oil fields. Electrical equipment has been provided for more rational planning and application of flooding operations in horizon III.

The flooding equipment for horizon III will be constructed as the realization of the various planned stages progresses.

The first section of equipment with an output of 400 cubic meters per 24 hours will begin operating after mid-1948.

Apart from horizon III of the Sagiz oil field, water flooding is planned for horizons I and II in the eastern portion of the Iskin oil field, as they appear to be favorable sites for flooding operations. These horizons have the physical and geological conditions appropriate for collectors: shallow position, great amount of residual oil, and also a considerable number of oil wells. It is planned to drill ten injection wells. The output of flooding plant I is to be 300 cubic meters per 24 hours. Jurassic horizons of the Koshkar deposit are also selected as sites for flooding.

Along with the extensive introduction of water flooding in the Kazakhstanneft' oil fields, the high efficiency of the Mariette method, utilized at the Krasnokamsk oil fields, is being taken into account. Plans have been made for its utilization in beds VII and VIII at Kulsary, which contain considerable amounts of residual oil.

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The presence here of gas-bearing horizons (V and others) assures a sufficient amount of gas as a working agent.

A thorough preliminary study of oil fields is also being conducted simultaneously at other deposits--Baychunas, Koschagyl, Narmundanak, etc.--with the objective of selecting other sites for the application of methods for intensifying oil extraction.

The wide range of application for secondary recovery methods will require increased study and research in all fields by the scientific research institutes, including the TsNIL of the Kazakhstanneft'.

In this connection, the TsNIL has provided for an organization combining the oil field's physics laboratory and a special group to study the operational conditions in the beds as a whole as well as in individual wells. It is urgently necessary to become familiar with the latest instruments for studying the physical and the chemical properties of fluids under conditions in the beds, and to provide for extensive and complete utilization of electric equipment when planning methods of increasing the bed's yield.

To gain the full value of experience from the application of flooding methods, a plant for experimentation and demonstration is being organized at the Makat base, with a special section for flooding.

A great responsibility for the timely execution of the secondary recovery projects lies with the construction organizations, the Kazakhstanneft' and the Glavgazneftestroy. Both must become familiar with the complicated hydraulic installations.

The successful execution of projects for the application of secondary recovery methods will permit the extraction from the ground of Kazakhstan of thousands of tons of additional high-grade oil, which is so indispensable to our great socialist nation.

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